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H. Sviatenko[1],
orcid.org/0000-0002-3117-2433,
O. Karpenko[2],
orcid.org/0000-0002-5780-0418,
V. Bukhtatyi[1],
orcid.org/0000-0002-6382-7801

1 – Ukrainian Research Institute of Natural Gases, Kharkiv, Ukraine, e-mail: henryfirst@ukr.net
2 – Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

OIL AND GAS BEARING POTENTIAL OF CRYSTALLINE BASEMENT IN DNIEPER-DONETS BASIN – UNBIASED VIEW

Purpose. Based on the analysis of existing information on the exertions of oil and gas in crystalline rocks of the Dnieper-Donets Basin (DDB), assess the presence of hydrocarbon deposits in certain fields and assess the prospects for the discovery of new ones.

Methodology. The study on oil and gas bearing capacity of the crystalline basement was based on the analysis of stock material on oil and gas fields of the Dnieper-Donets Basin, the study on petrographic composition of rocks in sections, analysis of results of well logging, petrophysical studies on rock samples from promising intervals of wells. The peculiarities of the structure of structural-tectonic models of hydrocarbon deposits with oil and gas exertions in the upper parts of the crystalline basement were also taken into account.

Findings. A significant number of drilling and well testing results, lithological-petrographic and petrophysical studies were analyzed, which allowed making objective conclusions about the existence of independent oil or gas deposits in the weathering crust of the crystalline basement at already known deposits. The conclusions also concerned the assessment of the industrial (commercial) attractiveness of the discovered deposits or oil and gas exertions in the upper parts of the crystalline basement of the DDB fields.

Originality. At the current level of study, it can be argued that within the Eastern Ukrainian oil and gas basin in the Archean-Proterozoic traps apart from the basal horizons of the cover, oil deposits were found in only three fields: Yuliivske, Ulianivske and Hannivske. Undoubtedly, there are hydrocarbon deposits in the Precambrian formations of DDB, but the most extensive discoveries in this direction of exploration and involvement in the development of already discovered accumulations seem to be still ahead. The geological situation should be realistically assessed for the presence of potential areas where the existence of common hydrocarbon deposits in the weathering crust of the foundation and the lower horizons of the sedimentary cover in the DDB is possible.

Practical value. The main value of this study is the real assessment of the existence of industrial accumulations of hydrocarbons in already discovered oil and gas fields in DDB. The myth of the presence of many oil and gas deposits in DDB in crystalline rocks of the crystalline basement, which without proper justification has repeatedly been found in the professional literature and in scientific reports at specialized conferences of various levels, has been debunked. Certain prospects for the discovery of oil and gas deposits in the crystalline basement of the Dnieper-Donets Basin are unmarked.

Keywords: *deposit, oil, gas, crystalline basement, petrographic studies, Dnieper-Donets depression, weathering crust*

Introduction. An integral feature of the current stage of forecasting the oil and gas potential of the subsoil is that researchers due to quite objective circumstances are forced to deal with objects that are of much more complex geological structure than those with which petroleum geology dealt earlier. The current stage of forecasting the oil and gas potential of the subsoil is characterized by a significant complication of the geological structure of the studied objects. Of increasing interest to field exploration are hydrocarbons, which are confined to the crystalline rocks of different ages of the sedimentary basin. This is due to global trends in reducing the growth of oil and gas reserves in some areas, as well as reducing the efficiency of oil and gas exploration, focused on traditional objects. Paradoxically, some of the deposits in these seemingly "non-standard" objects were discovered in the early stages of geological research, as is often the case in life, with much chance. For today, the accumulation and inflow of oil and gas of industrial importance, which are associated with the rocks of the basement, established in sedimentary basins of various types on almost all continents [1, 2], including Asia (Indonesia, China, Vietnam, India, Russia), the Middle East (Yemen), Africa (Algeria, Libya, Egypt), South America (Venezuela and Brazil), Canada, the United States (California, Kansas, Texas), the North Sea (Great Britain, Norway) [3]. Over the last decade, oil and gas production from crystalline basement reservoirs has intensified due to significant discoveries in the United Kingdom (Lancaster and Lincoln oil fields), Norway (Rolvsnes oil field), Chad oil fields (Central Africa) and large fields in crystalline rocks in Indonesia [4, 5].

Industrial oil and gas potential was found in the basement of 54 oil and gas basins of the world; it is more than 450 hydrocarbon deposits. The Pannonian Basin (Serbia) with a multi-age basement has the largest number of such deposits in Europe [6].

One of the first industrial inflows of oil and gas from crystalline rocks was obtained in December 1918 at the Panhandle-Hugoton field (USA); here as a reservoir are Precambrian biotite granites, liparite porphyries and diabases, which in the form of dykes and forces intrude the bodies of acidic magmatites and metamorphites. In 1925, a huge deposit was discovered in Venezuela, at the giant La-Paz oil field, where oil is contained, in particular, in fractured granites, granodiorites and various metamorphites at a maximum flow rate of 1.8 thousand m^3/day and the maximum depth of opening of crystalline rocks is about 940 m (Koshlyak V.A., 2002). In Libya, about 100 deposits are associated with basement rocks; most of them – "Augila-Amal", timed to the buried ledge of the Precambrian granitoids "Rakb". Total oil reserves are 512 million tons, production wells – from 100 to 1000 m^3/day. Oil deposits in igneous rocks of the basement have been discovered in Egypt, in the Suez Graben area. In 1974, 150 km off the west coast of India, a large Bombay field was discovered ("Bombay-High"). Large deposits of Sergipe Basin of Brazil: the Karmopolis field with initial oil reserves of 150 million tons; in Canada, the "Peace River"; North China's oil and gas basin – "Liaohe", "Dongxin", "Zhenqiu" and others. The discovery was made in Kazakhstan ("Oymash" deposit, 1981) and Ukraine, where several deposits in the crystalline rocks of the Dnieper-Donetsk basin were mapped.

In 1988, a unique "Bach Ho" (or "White Tiger") deposit was discovered on the mainland shelf of Vietnam, dedicated to the granitoid rocks of the Mesozoic basement [7]. "Vietsovpetro" Company, within the framework of a joint Russian-Vietnamese consortium, carried out targeted drilling for the basement, first on the "White Tiger", and then on other areas of the Mekong and South Conchon Basins, which are part of the oil and gas basin "Cuu-Long". This has led to the discovery of a number of new oil and gas fields ("Dragon", "Ruby", "Bavy", etc.), which play a crucial role in the fuel and energy sector of the Republic of Vietnam (the total share of deposits in the basement in the oil and gas industry here is more than 90 %). At the "White Tiger" field, the main oil deposits are associated with horst-like structures – the so-called "protrusions" of the Mesozoic crystalline basement. The oils of the basement deposits and the Lower Oligocene complex contain a significant amount of phytane, pristane and porphyrins, the original biogenic nature of which is beyond doubt (V. P. Gavrilov, Petroleum Geology, 1/2010). The pristane/phytane ratio in the oils of the basement deposits, sedimentary cover of the Lower Oligocene and organic matter of the lower Oligocene clay rocks is characterized by very close values, which may indicate their probable genetic relatedness. The productive interval of the section is represented by the alternation of zones of dense and dispersed fractured granitoid rocks, within which separate areas with increased crack density are distinguished. The orientation of cracks often changes with depth, forming several divergent systems. The main mass of cracks and small faults has a subvertical direction [7].

The first fountains of gas (Berezovsky district, 1953) and oil (Shaim district of Tyumen region, 1960) in Western Siberia were obtained from the pre-Jurassic age fold-metamorphic and crystalline base, represented at the Berezovsky field by biotite and biotite-hornblende gneisses of upper Proterozoic, injected with granites, and on the Mulimin Square of the Shaim Megaval – by Paleozoic crystalline rocks, but in subsequent years the search for hydrocarbons here was focused on Jurassic and Lower Cretaceous deposits [8, 9], where the main current deposits were identified. The interest in the accumulation of hydrocarbons in the basement was subsided.

The largest oil and gas fields in the basement formations are in strongly fractured rocks. The best types of rocks for the formation of foundation reservoirs are fractured and weathered quartzites and granites, because they are relatively fragile and, as a result, easier to destroy by tectonic stresses. Cracked gneisses are generally low-yielding, reservoirs are often of low quality; rocks are massive, dense, and cracks are often formed parallel to the stratification direction. Gneisses and shales are relatively malleable rocks, with a tendency to "smear" rather than destroyed under tectonic stress. Phyllites and other thin-layered crystalline shales are the least attractive in the sense of the element of fluid traps.

The largest oil and gas fields in the basement formations are in strongly fractured rocks. According to the author, the best types of rocks are fractured quartzites or granites, because they are fragile and, therefore, easier to destroy [10]. Cracked gneisses are low-productivity reservoirs, as they can be massive, dense or massive with open cracks parallel to the direction of rock stratification. Gneisses and shales are plastic and tend to "smear" and not collapse under the influence of tectonic stress. Phyllites and thin-layered shales are the least attractive, because such rocks are not fragile, they are layered and malleable, poorly destroyed.

Weathered granite rocks can also be excellent reservoirs, for example, at the Auguila-Naafora oil field in Libya. The following is a scale of the best types of crystalline basement rocks [10]:

- fractured quartzites (the best type of rock);
- cracked granites;
- cracked carbonates;
- weathered granites;
- cracked gneisses;
- weathered gneisses;
- cracked shales;
- weathered shales (the least preferred type of rock).

The same geological criteria are required for oil and gas fields in the foundation as for traditional oil and gas fields, which include reservoirs (fractured or weathered basement), oil and gas rocks adjacent to or overlapping the basement, structural tires that insulate deposits of basement.

Below are some of the most notable and high-profile discoveries of hydrocarbon deposits in crystalline basement rocks over the past 10 years.

Kali Berau Dalam gas field, South Sumatra. In 2019, the Spanish oil company Repsol announced that their Kali Berau Dalam-2 exploration well had discovered large gas deposits in fractured pre-tertiary basement rocks. This discovery expanded the development of gas in the basement 150 km northwest of the Suban field. It was reported that the well received gas at a rate of 45 million cubic feet per day. Repsol mentioned that at least 330 million barrels of oil equivalent were found as a result of the discovery of the gas field. For Indonesia, the discovery of Kali Berau Dalam is very important, as it is the largest discovery of oil or gas in 18 years since the opening of Cepu in 2001. In fact, oil analysts said that this discovery is one of the ten largest discoveries in the world for the last 12 months [10].

Chad. In 2013, the Chinese National Oil Company (CNPC) discovered oil in the Lanea-1 well in the Bogor Basin in a granite basement with a buried hill with an amplitude of 1,000 meters. This was followed by 5 more discoveries of oil and gas in the buried hills. Reservoirs are fractured granites and hydrothermally leached granites, the latter of which are the best facies reservoirs Oil-bearing rocks and tires are Early Cretaceous shales. The thickness of the oil part of the deposit is 1,500 meters, and the average productivity of the well is 1,500 barrels of oil per day. The reserves were estimated at about 100 million barrels, of which 70 % is in the basement and 30 % in the layer of granite that covers it [10].

Filtration-capacity properties of rocks in which the crystalline basement reservoirs are found are extremely diverse in genesis and quantitative parameters. The effective porosity of productive granitoids of the "White Tiger" reaches 5–18 %, crystalline reservoirs of "Penhandl" – 22 %, "Auja" – 14 % at permeability up to 820 mD; the maximum permeability of the bedrock at the "La Paz" deposit is 30 mD (Shuster V., Levyant V., Ellansky M. Oil and gas potential of the basement (problems of prospecting and exploration of hydrocarbon deposits), 2003).

Literature review. The struggle between theories of organic and inorganic origin of hydrocarbon compounds, which are now and probably will remain for a long time the energy basis of the global economy, in the world's scientific geological circles continues [11,12]. In the light of the significant number of unresolved issues, contradictions and gaps that exist in the evidence base of both concepts [13, 14], the reliability of information on each specific example of industrial deposits in igneous and metamorphic rocks, including those, which make up the crystalline basement of sedimentary basins [13, 15]. Consider the example of Dnieper-Donets basin (DDB).

Its North Side is considered to be the most promising for the search for hydrocarbons in the Eastern Ukrainian oil and gas basin. Here in the roofing part of the basement upper Proterozoic at depths of 80 to 450 m below its surface the reflection horizon VII is recorded. It correlates with the zones of boundaries of loosened rocks formed as a result of dynamometamorphism, maps the areas of abrupt changes in the petrographic composition of rocks and their physical properties in the zone of hypergenesis.

The total recorded thickness of the weathering crust on the northern side of the Dnieper-Donets basin varies from 3 to 87 m; it depends on the mineral composition of rocks, their structural and tectonic features, the degree of dismemberment of the paleorelief of the basement, the intensity of the manifestation of disjunctive tectonics, structural position. The depth of chemical weathering often increases in areas of fracture and void near rupture faults. The heterogeneity of the basement rocks contributes to the mosaic nature of the fracture, which has created conditions for the formation of tectoclase reservoirs, limited by the zone of absence of fractures.

Formation of roofing in the upper part of the basement. As the factual data presented in the works by V. Lebid and O. Rakovska (Collection of Scientific Works of the Ukrainian Geological Exploration Institute, No. 2/2014) show that hydrocarbon fluid deposits are often located at a certain depth from the surface of the crystalline basement. This is typically not only for DDB deposits, but also for deposits in other regions (White Tiger, La Paz, Oimasha, Romashkinske field, etc.). Therefore, there is reason to believe that in the roof of the "secondary-decomposed reservoirs" may form a layer that will act as a tire. In the DDB, its thickness varies from 0 to 45–50 m, and the maximum reaches more than 150 m. Based on the applied provisions of fluid dynamics, these two phenomena are closely related (V. Lebid, O. Rakovska, 2014). Thus, these authors believe that during the fall of migratory stresses in the surface part of the crystalline basement there is not only mechanical compression of tectonic cracks, but also supersaturated solutions are formed. Most often, this role is performed by calcite, which is formed from the most mobile element here – carbon dioxide. In addition to calcitization, sideritization and quartization of rocks often occur. Associations of these and similar rocks form (under favorable circumstances) in the fluid-conducting zones of the crystalline basement a dense surface tire. Thus, low-temperature hydrothermal processes contribute not only to the formation of reservoir rocks, but, ultimately, the formation of roofing tires (bulkheads), especially when there is an active replacement of aluminosilicates by minerals of the kaolinite group. Roofing tires are zonal and sometimes local in nature.

Purposeful study on the prospects of the Precambrian in DDB began in the 70s of the twentieth century as part of a regional search program developed by leading geologists, proponents of inorganic theory of hydrocarbon origin (Porfiriev V., Sollogub V., et al., 1975); it was realized only partially, which, nevertheless, led to the discovery of a number of petroleum deposits.

The study on the entire section of the Precambrian formations opened by wells on the North Side of the DDB allowed us to identify below the weathering crust in the thickness of unchanged by weathering crystalline rocks of the basement of the tectonite zone (expansion, fragmentation, inhomogeneities) and form the effect of "layered pie" (Chebanenko I., Krayushkin V., Klochko V., Gozhik P., et al. Oil and gas-bearing of the basement of sedimentary basins, 2002). They are characterized by a decrease in the electrical resistivity of individual layers, resulting in an alternation of tight and loose rocks; on the curve of neutron gamma-ray logging (NGR) against the background of high values, areas with smaller values are distinguished, which corresponds to the presence of fractured or undisturbed zones; the curves of sonic logging, lateral and micro- lateral logging on the features of the characteristics do not differ from those in the zone of disintegration of the weathering crust; the caliper logs have an unstable character, significantly deviating in the direction of cavernous formation. Quantitative indicators (effective thickness, porosity and saturation coefficients) are quite difficult to obtain due to the lack of reliable petrophysical interpretation models.

Filtration-capacity properties of the upper part of the crystalline rocks of the basement, no doubt, are conditioned by the presence of reservoirs and fluid saturation. All recorded oil and gas manifestations are tied to selected zones with high filtration-capacity properties in the basement.

Weathering crusts, as well as zones of seals, have independent significance in relation to the prospects of oil and gas potential. The rocks of the crystalline basement (the upper part) are an independent object of oil and gas exploration.

The distribution of weathering crusts is regional within the North Side. The nature of fluid saturation indicates a significant heterogeneity in the structure of the cavity space of the foundation. Most often, you can determine the horizontal crack-cotton. In some intervals, the fracture varies from horizontal to vertical.

In the weathering crust there are such zones (from top to bottom):

1. Clay zone (kaolinization). This is the final stage of destruction of the crystalline base. The clay rocks formed in this case are characterized by low electrical resistivity, high differentiation of well caliper, relatively high performance on acoustic logging curves. The thickness of the zone mainly does not exceed 20 m. According to geophysical criteria, the clay rocks of the weathering crust of the basement differ from the sedimentary ones. The basal layer of the sedimentary cover can directly lie on the weathering of the basement. The break between the basement and the overlying sediments should be carried out on the base of the basal horizon of the sedimentary cover (Chebanenko I., Krayushkin V., Klochko V., Gozhik P., et al. Oil and gas-bearing of the basement of sedimentary basins, 2002).

2. Leaching area. In the leaching zone, some elements of the structure of tight oil and gas source rock have been preserved, which on the curves of lateral (LL) and micro-lateral (MLL) logging is reflected by increased resistivity values of some low-power strata and low values of more destroyed rocks; sharply the values on the sonic logging curves (SL) increase. The thickness of the zone is from 0 m 26 m.

3. Zone of disintegration. The curves of electrical resistivity and neutron gamma-ray logging are more dissected; SL curves record the alternation of high-speed sections of tight rocks and sections of rocks with a significantly lower speed, which have undergone compaction; layers with sharply reduced resistivity are marked on the LL and MLL curves. The thickness of the zone is 2–55 m (well 6-Prokopenkivska – 6 m, well 5-Khukhrynska – 46 m).

4. Unchanged basement by weathering processes. High values of resistivity and NGR are fixed here; high acoustic speed; on the LL and MLL curves a "roof" of electrical resistivity is formed; indicators of gamma-ray logging (GR) are significantly increased; caliper notes layers with nominal well diameter.

At present, the State Balance of Minerals of Ukraine records oil deposits, which are believed to be located in the reservoirs of the Archean-Proterozoic basement of the Dnieper-Donets basin and its weathering crust, at 7 fields: Khukhrynsky oil-gas-condensate field, Yuliivske oil-gas-condensate field, Skvortsivske oil-gas-condensate field, Ostroverkhivske gas-condensate field, Hashynivske oil field, Hannivske oil field of the Northern Side of the DDB and Ulianivske oil-gas-condensate field of the Southern Coastal zone of the depression. At the Skvortsivske, Ostroverkhivske, and Hashynivske fields, the Precambrian deposits are accounted for as a single object together with the Paleozoic horizons (the Visean stage and the upper Devonian system). Quite a number of oil and gas manifestations associated with the reservoirs of the basement are known in a number of structures [15].

The authors of this paper believe that it is necessary to clearly understand the difference between those fields where oil and gas is localized in a single reservoir formed by the rocks of the zone of decomposition and secondary transformation of crystalline reservoir and reservoirs of the basal layers of the cover directly the roof of the Precambrian, and those where deposits are formed in the traps of the basement (including its weathering crust, if it can be reliably identified) separately [15]. Based on the audit of the actual material (description and analysis of the core, test reports of wells, the results of well logging, etc.) [16, 17], they came to the following conclusions.

Unfortunately, in scientific publications, which consider the prospects of oil and gas in the basement of the oil and gas basins of our country, from time to time there is information that, to put it mildly, does not correspond to reality. Thus, reports of the discovery of a gas deposit in the metamorphites of the South Yevheniivska structure by the 4-Yevheniivska well were premature; in fact, the influx of hydrocarbons was provided by a productive layer of sandstones of the regional horizon S-8 of the Upper Serpukhovian substage by emergency overflow behind a poorly cemented casing, which was proved by special studies. The same applies to the first industrial gas inflow in well 591 of the Ostroverkhivske gas-condensate field, where in reality the gas-emitters were not crystalline Precambrian rocks, but Upper Visean psamites (horizon V-16).

Research methods and results. The results of interpretation of seismic materials cannot be a direct proof of belonging of one or another part of the section to a certain stratigraphic interval, which the authors of the work tried to do (Chebanenko I., Krayushkin V., Klochko V., Gozhik P., et al. Oil and gas-bearing of the basement of sedimentary basins, 2002) about oil and gas industrial potential of the interval of well section 1-Rakitnianska to the roof of the basement. There are numerous examples of discrepancies between the reflection horizon VII, determined by 2D seismic surveys, the boundary of the cover-basement section at 500–1000 m; errors of this scale were revealed, in particular, at Druzheliubivska and Ulianivska structures. The exact definition of this boundary is possible only by a comprehensive analysis of well logging data [16, 18] and core material. It should be borne in mind that the interpretation of the results of remote sensing methods can contain significant errors – even the most modern volumetric modifications of seismic and even in terms of quality performance are inaccurate in the first tens of meters [19]. Disintegrated crystalline and carbonate-terrigenous rocks of the basal layers of the cover are sometimes impossible to distinguish in the logging diagrams. And the quality of core binding by depth in the absence of independent quality control of primary calculations performed by drilling crews also often leaves much to be desired. Methods of non-traditional interpretation of well logging data can help here [16, 20]. Thermometric studies must be performed during the joint testing of the horizons of the cover and the Precambrian roof in order to correctly determine the inflow profile, which is often neglected in the real conditions of the modern production process.

Taking into account the above, let us say that the presence of industrial oil and gas deposits in the upper Precambrian rocks at the ynske field, the first in the DDB, where industrial deposits of hydrocarbons in the crystalline basement were officially discovered (1985), certainly not proven. All inflows of oil and gas from the basement rocks during the test were obtained in those wells in the sections of which there are productive layers of horizon V-21 (wells 9-Khukhrynska, 1, 2, 3, 22-Chernetchinska) and horizon V-20 (wells 1-Khukhrynska, 7-Chernetchinska) Upper Visean substage, which are 5–15 m above the intervals of testing of rocks. In addition, all samples, including deep, taken from the intervals of perforation of columns against crystalline rocks and horizons V-21 and V-20, in physicochemical properties and composition are almost the same for the same wells and in general on the field. These data, as well as the results of experimental operation of wells 1-Khukhrynska, 9-Khukhrynska, 22-Chernetchynska and others, unfortunately, do not indicate the existence of industrial hydrocarbon deposits in the upper part of the basement rocks in the area.

Given the extremely limited selection of rock material in exploration wells and the lack of special industrial and geophysical studies, it must be stated that at the Gashynivske and Skvortsivske deposits it is now impossible to prove that industrial-productive intervals belong to the Archean-Proterozoic reservoirs separated from the bottoms of productive sedimentary strata.

The basement rocks on the Skvortsivske deposit are mostly gray granites with a greenish tinge due to the chloritization of biotite, medium-large crystalline. According to the results of laboratory studies on the core, the porosity of the crystalline rocks varies from 0.1 to 5.1 %, the gas permeability of most samples is much lower than 1.0 mD. One sample from the well 46 has a permeability of 1.28 mD. The weathering crust of Proterozoic rocks is represented by rubble of weathered, chloritized gneiss. The basal horizon-umbrella of the sedimentary cover at Skvortsivske oil-gas-condensate field is of the Visean age and is represented by light gray sandstone, multi-grained with gravel and quartz pebbles. There are metosomatically altered fractured metamorphites the open porosity of which reaches 5.2 %, and gas permeability in isolated cases – 1.79 mD porous and 12.40 mD fractured. The weathering crust and basal sandstones are in many cases separated by only one or two meters of pelitic layer, so they are considered as a single reservoir.

In the "reference" well 26-Skvortsivska in the range of depths of 3,140–3,149 m tested with a powerful inflow of oil and gas is the basal horizon, represented here by well logging as a sandstone with a porosity of 10.5–14.0 % and, perhaps, the very roof of the Precambrian rocks. The core was not extracted from this part of the section

In the well 1-Hashynsvska, the basement horizon is characterized by a core in the range of 3,648–3,650 m. These are tight quartzites (removed 0.8 m) and garnet-quartz-biotite shales (removed 1.2 m). According to the results of laboratory studies, their porosity ranges from 0.1 to 0.4 %, permeability – from completely impermeable to < 0.01 mD. No signs of hydrocarbon saturation were observed. It should be recalled that the tested filter with industrial oil inflow depth range of 3,555–3,647 m also covered the Upper Devonian volcanic-sedimentary stratum.

There is no doubt that the industrial inflow of gas and oil to the basement rocks in well 2 of the Yuliivske field is correct. In it, crystalline rocks were tested in the range of 3,636–3,735 m by a filter, in the range of 3,735–3,800 m by an open bore. During the test on the fitting with a diameter of 6 mm, the inflow of gas with a flow rate of 61.4 thousand m^3/day and oil with a flow rate of 11.5 m^3/day was obtained. The reservoir pressure was 37.78 MPa at a depth of 3,685.5 m. According to the core material, the basement rocks in well 2 were discovered from a depth of 3,533 m and are represented by diorites, gneisses, plagiogranites (partially cataclased), amphibolites (including granitized ones), metasomatites (plagiomigmates and amphibolites), and chofibolites. The porosity of gneisses at the core reaches 5.5–6.1 %, gas permeability – 0.25–5.62 mD. Zones of increased permeability are confined to fractured, stratified cataclysmic and metasomatically altered rocks. In the most wells of the Yuliivske field, crystalline rocks are practically impermeable [15].

Thus, in the 25-Yuliivska well, three cores were raised from Precambrian rocks. In the range of 3,868–3,873 m, the core is represented by weathering crust on granite gneisses (thickness 3.7 m); open porosity ranges from 2.0 to 9.9 %, an average of nine definitions is 6.9 %, permeability ranges from almost impermeable samples to 0.01 mD, or with very low permeability to cracks; no signs of hydrocarbon saturation were detected. In the range of 3,950–3,960 m, the core is represented by gneisses, which are practically not reservoirs.

In the 26-Yuliivska well, the Precambrian horizon is characterized by a core in the range of 3,648–3,650 m, which is represented by weathered granite gneiss (2.7 m) and granite gneiss (0.1 m). According to the results of laboratory studies, the porosity ranges from 3.6 to 8.7 %, the average for seven determinations is 6.3 %, the permeability barely reaches 0.01 mD. No signs of hydrocarbon saturation were recorded.

In the 73-Yuliivska well, a core from the crystalline base was raised in the range of 3,560–3,568 m, represented by weathered greenish-gray plagiogranites of muscovite-quartz-oligoclase composition (1.6 m). The porosity ranges from 3.0 to 5.5 %, the average of six determinations is 4.4 %, the permeability is up to 0.91 mD in one sample with a crack. There are no direct signs of saturation of the rock with oil or condensate.

In the 75-Yuliivska well, the core was selected from the foundation in the range of 3,687–3,695 m, it is represented by weathered greenish-gray granite gneisses (2.8 m). The porosity ranges from 0.1 to 9.6 %, the average value of the seven definitions is 3.1 %, the permeability ranges from completely impermeable samples to < 0.01 mD. There are no signs of hydrocarbon saturation.

The industrial inflow of oil from the basement was obtained at one time at the Ulianivske field in the well 5, information about which is not disseminated in open sources. In the range of 3,055–2,982 m, the zone of crystalline rocks was tested by a filter; the inflow of gas, oil and formation water was obtained. With an average dynamic level of 1,017.5 m, the gas flow rate was 1.1 thousand m^3/day, oil – 11.3 m^3/day, formation water – 3.6 m^3/day. According to the results of thermometric studies, it was found that the oil and gas emitter range is 2,982–3,036 m, – Precambrian.

In the well 5-Ulianivska, rocks of crystalline basement are characterized by two cores in the intervals 2,995–3,000 and 3,050–3,055 m, represented by gray granite-gneiss amphibole-biotite-quartz-feldspar composition; in the latter – with areas of secondary disintegration; the porosity of rocks ranges from 2.9 to 4.0 %, the maximum permeability is 0.08 mD.

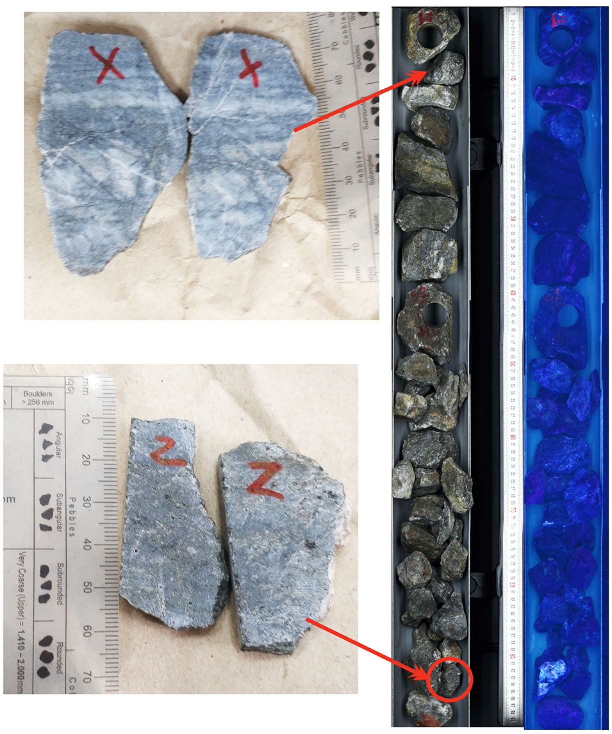
In the well 14-Ulianivska, the core selected in the range of 3,070–3,080 m is represented by light gray plagiogranite, biotite-quartz-plagioclase composition, medium-crystalline, massive texture, pyritized by cracks, without macroscopic signs of hydrocarbons. The rock is actually impermeable (porosity is 0.1 %). Methane gas inflow with a flow rate of 1.1 thousand m^3/day was obtained from the range of 3,030–3,180 m in the open wellbore.

In 2019, in the exploration well 1-Hannivska, drilled on the northern border of the Shevchenkivskyi structural bay according to the project of Ukrainian Research Institute of Natural Gases (Kovshikov A. and others), with a high probability from the Precambrian crystalline rocks an industrial inflow of oil with a density of 0.813 g/cm^3 was received (Fig. 1). After opening the depth range of 3,732–3,727 m by perforation in the production column, the oil flow rate was 7.9 m^3/day at an average dynamic level of 1,810 m; pressure at the closed wellhead was 2.0 atm. In the composition of the gas dissolved in oil, the content of which is insignificant, the presence of helium was not recorded.

In the 1-Hannivska well, dark gray, cataclyssed, chlorinated, coarse-grained, large-giant crystalline gneiss was raised from the interval 3732.5–3733.5 m, with a developed system of cracks, through which oil slicks were observed and the smell of hydrocarbons was felt (Figs.1–3). The open porosity ranges from 2.3 to 2.8 %, the permeability of one sample with a crack is up to 0.28 mD.

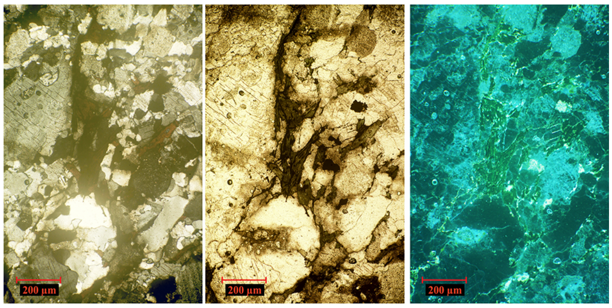
It should be noted that to date, hydrocarbon deposits found in the reservoirs of the basement at the DDB deposits are not developed; thus, their industrial value is determined conditionally.

Conclusions. At the current level of research, it can be argued that within the Eastern Ukrainian oil and gas basin in the Archean-Proterozoic traps apart from the basal horizons of the cover, oil deposits were found at three fields: Yuliivske, Ulianivske and Hannivske. In this context, the loud statement about the large zone of oil and gas accumulation in the crystalline basement found on the North Side of the DDB is somewhat surprising: literally [13]: "...as an alternative we can cite the example of the implementation of the ideas of deep genesis of oil, which led to the opening in 1985 of a large zone of oil and gas accumulation in the crystalline basement on the Northern side of the Dnieper-Donets basin developed in Ukraine during the Soviet era under the leadership of Academician V. B. Porfiriev (Chebanenko, and others, 2004). According to the oral report of V. O. Krayushkin, the size of this zone is 35–50 km wide and over 400 km long, up to 50 oil and gas fields have been discovered in the basement, including the giant Markivske with reserves of up to 100 million tons of oil. Gas and oil with flow rates of 3 million m^3/day and 350 tons/day are gushing from amphibolites and plagiogranites of the crystalline basement" [12, 13].



a *b* *c*

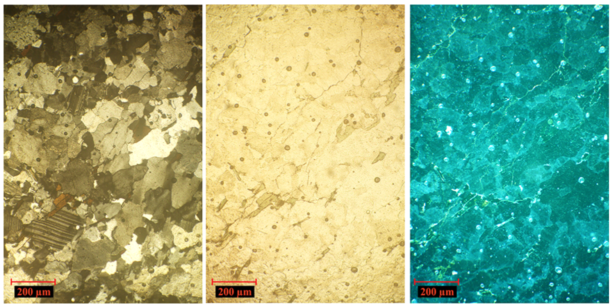
Fig. 1. Well 1-Hannivska. The core, raised in the range of 3732.5–3733.5 m, and the location of the samples from which the petrographic sections are made (a); left – white light (b), right – ultraviolet (c)



a *b* *c*

Fig. 2. Well 1-Hannivska. Photomicrograph of the rock thin section X. Gneiss hornblende-plagioclase-quartz. The system of cracks on which luminescence of hydrocarbons is observed is well noticeable:

a – crossed nicoli without an analyzer; b – without analyzer; c – in reflected ultraviolet light. Small balls are air, a defect in making a thin section



a *b* *c*

Fig. 3. Well 1-Hannivska. Photomicrograph of the thin section Z. Gneiss hornblende-plagioclase-quartz. The system of cracks on which luminescence of hydrocarbons is observed is well noticeable:

a – crossed nicoli without an analyzer; b – without analyzer; c – in reflected ultraviolet light. Small balls are air, a defect in making a section

Undoubtedly, there are hydrocarbon deposits in the Precambrian formations of DDB, but the most extensive discoveries in this direction of exploration and involvement in the development of already discovered accumulations seem to be still ahead. Of course, the arsenal of research methods on oil and gas deposits in crystalline rocks should include the latest technologies for interpretation of well logging data, which allow assessing the presence of hydrocarbons in the presence of large areas of filtration and fractured rocks [17, 19–21]. In addition, the geological situation should be realistically assessed for the presence of potential areas where the existence of joint hydrocarbon deposits in the weathering crust of the basement and the lower horizons of the sedimentary cover in the DDB is possible.

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Нафтогазоносність кристалічного фундаменту Дніпровсько-Донецької западини – неупереджений погляд на стан проблеми

Г.Є. Святенко[1], *О.М. Карпенко*[2], *В.М. Бухтатий*[1]

1 – Український науково-дослідний інститут природних газів, м. Харків, Україна, e-mail: henryfirst@ukr.net
2 – Київський національний університет імені Тараса Шевченка, м. Київ, Україна

Мета. На основі аналізу існуючої інформації щодо проявів нафтогазоносності у кристалічних породах фундаменту Дніпровсько-Донецької западини (ДДЗ) оцінити наявність промислових покладів вуглеводнів на окремих родовищах і перспективи відкриття нових.

Методика. Дослідження нафтогазоносності фундаменту базувалось на аналізі фондового матеріалу по родовищах нафти й газу Дніпровсько-Донецької западини, вивченні петрографічного складу порід у шліфах, аналізі результатів промислово-геофізичних досліджень, петрофізичних досліджень зразків гірських порід із перспективних інтервалів свердловин, результатів промислових випробувань пластів. Також до уваги приймались індивідуальні особливості будови структурно-тектонічних моделей родовищ вуглеводнів із нафтогазопроявами та вже виявленими покладами у верхніх частинах кристалічного фундаменту на родовищах ДДЗ.

Результати. Проаналізована значна кількість результатів буріння й випробування свердловин, дані літолого-петрографічних і петрофізичних досліджень, що дозволили зробити об'єктивні висновки стосовно існування самостійних покладів нафти або газу в корі вивітрювання та нижчезалягаючих зонах фундаменту на вже відомих родовищах. Висновки стосувались також оцінки промислової (комерційної) привабливості виявлених покладів або нафтогазопроявів у верхніх частинах кристалічного фундаменту на родовищах ДДЗ.

Наукова новизна. На нинішньому рівні вивченості можна стверджувати, що в межах Східно-Українського нафтогазоносного басейну в архей-протерозойських пастках окремо від базальних горизонтів чохла виявлені поклади нафти лише на трьох родовищах: Юліївському, Ульянівському й Ганнівському. Поклади вуглеводнів у докембрійських утвореннях ДДЗ існують, але найбільш масштабні відкриття у цьому напрямі розвідки й залучення до розробки вже виявлених скупчень ще попереду. Слід реально оцінювати геологічну ситуацію щодо наявності потенційних ділянок, де можливе існування спільних покладів вуглеводнів у резервуарах фундаменту та нижніх горизонтах осадового чохла у ДДЗ.

Практична значимість. Основна цінність даного дослідження полягає в реальній оцінці існування промислових скупчень вуглеводнів на вже відкритих родовищах нафти й газу у ДДЗ. Скасовано міф про вже встановлену наявність багатьох промислових покладів нафти й газу у ДДЗ у кристалічних породах фундаменту, інформація про що без належного обґрунтування наводиться у фаховій літературі та в наукових доповідях на профільних конференціях різного рівня. Намічені певні перспективи відкриття покладів нафти й газу у кристалічному фундаменті Дніпровсько-Донецької западини.

Ключові слова: *поклад, нафта, газ, кристалічний фундамент, петрографічні дослідження, Дніпровсько-Донецька западина, кора вивітрювання*

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